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ALMOND POLLINATION

BY

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ALMOND POLLINATION

By WARREN P. TUFTS

For the successful production of orchard crops there are certain important limiting factors to be considered. In the culture of the almond freedom from late spring frosts, a deep and well-drained soil, and the interplanting of proper varieties to secure cross-pollination, are the chief "limiters."

Almonds were planted in California as early as 1853, but records show that the tonnage of the early orchards was quite variable. The failure of these plantations was due largely to a lack of knowledge of the factors controlling the successful production of the almond. Gradually it became a recognized fact that the almond, on account of its early blooming habit (in certain sections of California sometimes as early as late January), and its aversion to heavy and poorly-drained soils, would succeed commercially only in certain locations—that is, where there is little danger from late spring frosts and where the soil is deep and well drained.

That there is a distinct pollination problem with the almond was recognized as early as 1885, when Mr. A. T. Hatch,[1] of Suisun, California, pointed out the fact that Languedoc trees near seedlings always produced heavier crops than when planted in solid blocks. On account of its reputation for light bearing the Languedoc variety was rapidly displaced by the Nonpareil, I. X. L., and Ne Plus Ultra varieties, seedlings originated and introduced by Mr. Hatch in the early 90's. Many of the later orchards also were planted in unsuitable places, there being a feeling that these new improved varieties would prove profitable under all conditions. In addition to the failure of the orchards planted in unfavorable locations, many instances[2] are on record as to the non-bearing of the Hatch varieties where the only plausible explanation is that of lack of proper cross-pollination.

THE PROBLEMS OF ALMOND POLLINATION

In carrying out the work of which this bulletin is a progress report, an attempt was made to solve the following problems for California conditions:

[1] California State Board of Horticulture Reports, 1885–1886, p. 326.

[2] Dargitz, J. P., Pacific Rural Press, vol. 72, no. 10, Sept. 8, 1906.

1. What varieties of almonds commercially grown in California will be profitable when planted in solid blocks—i.e., without pollenizers? This is a question of self-fertility.*

2. What varieties planted in solid blocks will not be profitable? This is a question of self-sterility.*

3. If the commercial varieties of almonds at present grown in California will not produce profitably without providing for cross-pollination, which varieties should be planted together? This is a question of inter-fertility.

Even though two varieties may be inter-fertile, the following points should always be considered in selecting pollenizing varieties:

(*a*) Commercial value of the pollenizer.

(*b*) Coincidence of bloom of the pollenizer with the variety to be pollinated.

(*c*) Succession of ripening of varieties for convenience in harvesting.

(*d*) Amount of pollen produced by the pollenizer.

(*e*) Germinability of the pollen produced by the pollenizer.

ORGANIZATION OF THE WORK

The methods employed for the solution of the problems just outlined were those commonly in use in cross-pollination experiments.[3] Briefly stated, this part of the work consisted in the application by hand of the pollen desired, having first removed the flowers' own pollen-producing organs (the stamens). The introduction of foreign pollen through the agency of wind and insects was prevented by covering the hand-pollinated blossoms with paper sacks. Accurate counts of the flowers of the various varieties thus treated with pollen of different kinds were made and recorded. Later in the season the sacks were removed. The fruits resulting from these artificial pollinations were counted and the proper records made after the first and second drops and again at harvest.

During 1910 the work was carried on by B. S. Brown,[4] and during

[3] The Division of Pomology has in preparation a bulletin dealing with the more technical phases of the whole pollination question. In this publication the "technique" employed in the solution of various pollination problems will be discussed in detail.

[4] Brown, B. S., Almond Culture, a thesis presented as partial fulfillment of the requirements for the Master's degree from the University of California, 1911.

* The writer prefers the terms, "barren" and "fruitful," as explained by Kraus in the *Journal of Heredity*, vol. 6, no. 12, pp. 549–557, rather than the inexact terms, "sterile" and "fertile." The latter terms have been used in this paper, due to the fact that the general public is more or less familiar with these expressions as herein used.

1915 by W. E. Gilfillan.[5] The data for these two years are of little value in themselves, because the numbers employed were relatively small. During 1916 the work was largely confined to the determination of the question of self-sterility, and in 1917 the same work was repeated and many cross-pollinations made. In 1918 repetition of all self-pollinations and crosses was again made, but frost in the University orchards at Davis vitiated the whole season's effort with the exception of the experiments performed on the Nonpareil variety which were carried on in the orchard of Mr. G. W. Pierce, some six miles distant from the University Farm.

With the exception just noted all experiments were conducted in the University orchards at Davis. The trees in the University orchard are all young and vigorous, having been planted during the spring of 1908. In the Pierce orchard the trees are in fair vigor. This orchard was planted in 1892.

THE BLOOMING PERIOD OF CERTAIN ALMOND VARIETIES

Almonds have a relatively long period of bloom if the total time from the opening of the first blossoms to the shedding of the petals is considered. Many growers are of the opinion that even the later blooming varieties overlap sufficiently with the earlier varieties to set a crop on the latter. Such a selection of varieties, however, is not to be generally advised, although in some cases it may be desired to use a variety listed as an early bloomer to pollenize a late bloomer. Based on what may be called the period of effective bloom, varieties may be roughly divided into early and late bloomers as shown in the following lists. The Nonpareil has been included in both lists as being just about midway:

Early Bloomers	*Late Bloomers*
Big White Flat	Dickinson
California	Drake
Harriott	Eureka
I. X. L.	Golden State
Jordan	Languedoc
King	Nonpareil
Klondike	Reams
Lewelling	Sellers
Ne Plus Ultra	Texas
Nonpareil	
Peerless	
Princess	
Silver Shell	

[5] Gilfillan, W. E., Pollination of the Almond, a thesis presented as partial fulfillment of the requirements for the Bachelor's degree from the University of California, 1915.

The accompanying chart (page 341) gives the average blooming seasons of certain almond varieties for the years 1914 to 1918, inclusive, unless otherwise noted. The date of bloom is of course dependent on many factors, such as soil, season and location.

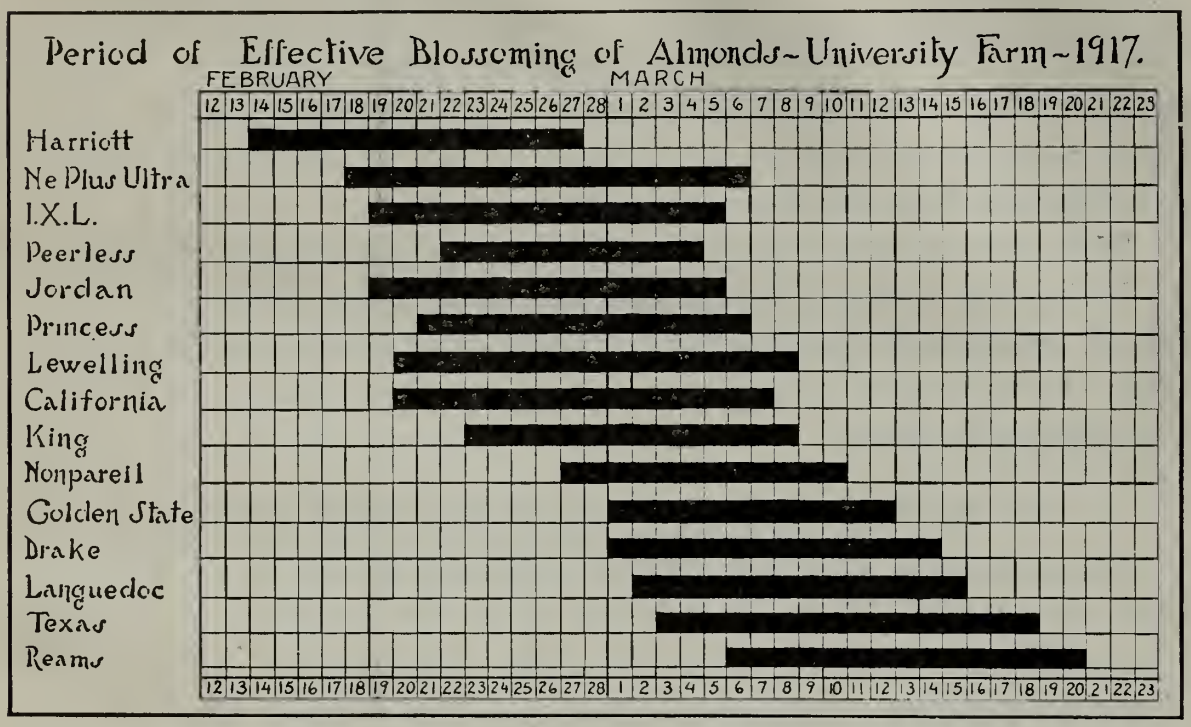


Fig. 1.—The effective blooming period of certain almond varieties during the season of 1917. The dates in this table cover the time each variety was in conspicuous bloom and therefore of maximum attraction to insects.

POLLEN PRODUCTION OF ALMOND VARIETIES

In addition to the inquiry into the viability of the pollen produced and the date of bloom of a certain variety, the orchardist in selecting a pollenizer for his commercial orchard must take into consideration whether the variety to be planted as a pollenizer is a good pollen producer. In practically all instances the pollen production of the first almond blossoms was noted to be quite inferior in quantity to that produced by flowers maturing several days later.

Data covering the abundance of pollen production have been collected for only two seasons. The results are presented herewith.

Pollen Production of Seventeen Almond Varieties

Variety	*Pollen production, 1917*	*Pollen production, 1918*
Big White Flat	Abundant	Very abundant
California	Abundant	Very abundant
Drake	Very abundant	Very abundant
Golden State	Abundant	Medium to shy
Harriott	Abundant	Abundant
I. X. L.	Abundant	Abundant

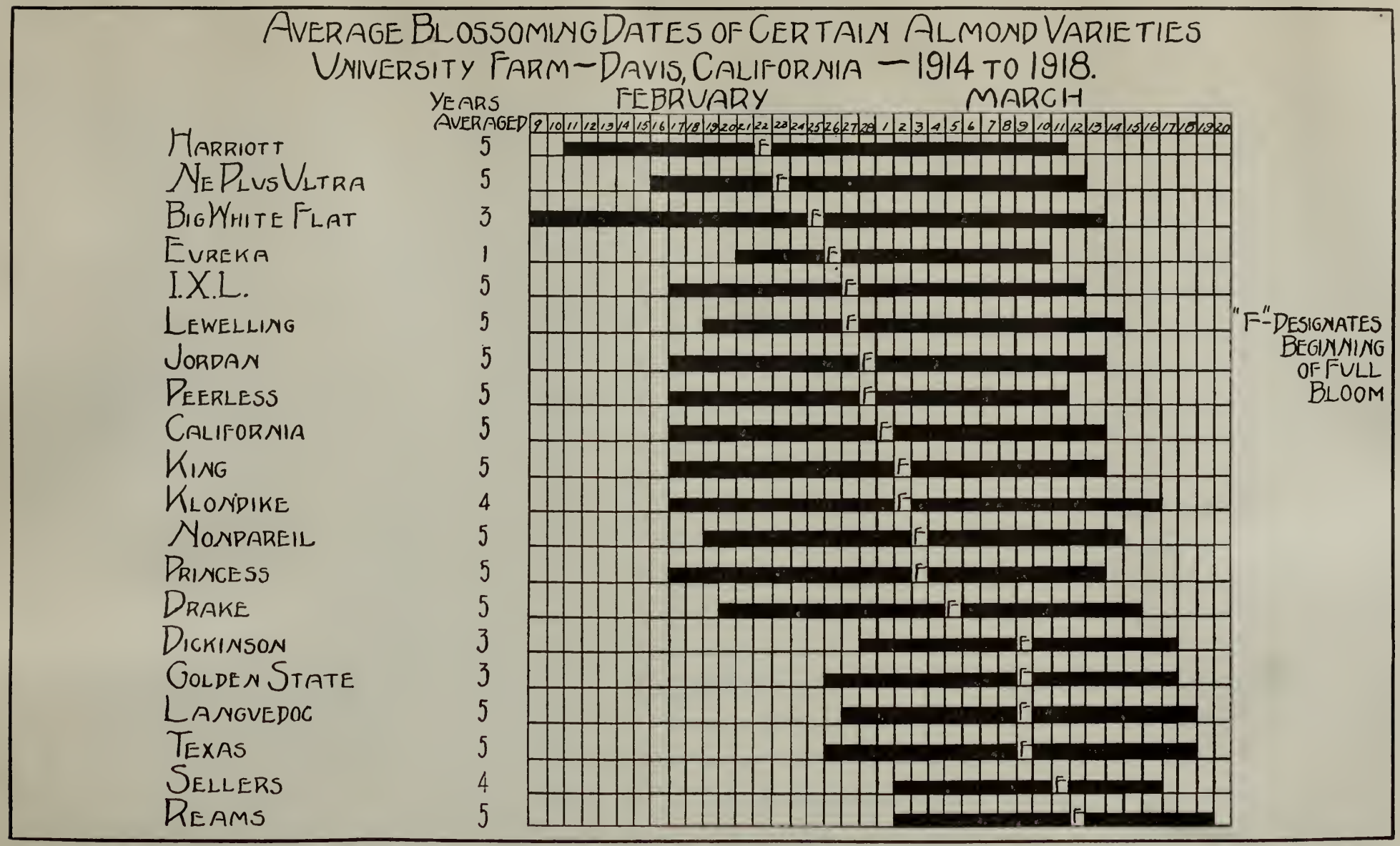


Fig. 2.—The average dates of the first, last, and full bloom of certain almond varieties covering a period, in nearly all instances, of five years. The number of years averaged is shown in a separate column for each variety.

POLLEN PRODUCTION OF SEVENTEEN ALMOND VARIETIES—(*Continued*)

Variety	*Pollen production, 1917*	*Pollen production, 1918*
Jordan	Medium to shy	Shy
King	Medium	Medium
Klondike	Abundant	Medium
Languedoc	Very shy	Medium to shy
Lewelling	Abundant	Medium
Ne Plus Ultra	Abundant	Abundant
Nonpareil	Abundant	Abundant
Peerless	Abundant	Abundant
Princess	Abundant	Abundant
Reams	Abundant	Abundant
Texas	Medium to abundant	Abundant

GERMINABILITY OF THE POLLEN USED

The pollen used in all experiments was in prime condition and showed in all cases quite a satisfactory artificial germination test. In many instances pollen collected from early maturing flowers proved to be of very poor viability as compared with that produced by later blossoms on the same tree.

TABLE I.—GERMINABILITY OF POLLEN, SEASONS 1915–1918

Figures give per cent germination in 12 per cent cane sugar solution

Variety	1915	1916	1917	1918
Big White Flat	....	....	93	76
California	....	75	37	77
Dickinson	....	....	51	....
Drake	94	35	33	32
Eureka	....	....	....	14
Golden State	....	....	25	32
Harriott	92	76	80	88
I. X. L.	85	80	94	60
Jordan	73	50	85	64
King	....	80	33	48
Klondike	....	....	89	86
Languedoc	44	28	12	15
Lewelling	88	90	69	65
Ne Plus Ultra	89	83	94	74
Nonpareil	90	88	53	44
Peerless	....	50	24	60
Princess	81	63	39	37
Reams	....	90	....	53
Sellers	....	....	....	64
Texas	85	86	60	16
Average	82.1	69.5	57.1	52.8

During the first two seasons weather conditions during the blooming period of almonds were quite favorable for the setting of fruit

and, as a consequence, very high germination tests were recorded. During 1917 and 1918, however, wind, cold and rain destroyed to a marked degree the viability of the pollen. But inasmuch as only one viable pollen grain is actually necessary to effect fertilization, and since by actual count it was determined that from sixty to one hundred and twenty-five pollen grains were deposited on the stigma of each flower artificially pollinated, there need be no fear as to the accuracy of the results during the latter two seasons, due to low viability of the pollen employed.

RELATION OF NORMAL SET TO FINAL CROP

Immediately after the petals fall each flower begins to form a fruit. During the following two or three weeks a certain percentage of these young fruits drop and only a rather low percentage of the total number of original blossoms continues to develop. It is quite necessary for this drop to take place, as the tree under average circumstances would never be able to carry so many fruits through to maturity. The factors determining which of these young fruits shall drop are not at present fully known. Later in the season there takes place still another falling of young fruits known as the "June drop."

The expression *normal set,* is a more or less technical term for designating the percentage of fruit which the tree sets under normal conditions when left open to insect pollination. It is obvious that the normal set may be determined at any time up to the end of the season by counting the fruits on a tree and comparing the number with the original bloom. In these experiments approximately 2000 blossoms of each variety well distributed over the trees were counted each year and proper records kept to determine the normal set after the first and the second drop, and at harvest time.

The questions at once arise as to what percentage of normal set at harvest time constitutes a full crop and what is meant by a "full crop." What constitutes a full crop of any fruit is perhaps largely a question of judgment or guess. It varies with such factors as variety, soil and moisture conditions. What would be considered a full crop under foothill conditions would not necessarily be the same in a valley location. In order to secure some idea on this most important phase of the subject, table II is herewith presented which gives the normal set of certain almond varieties for the years 1916 and 1917, together with the average yield of these trees reduced to an acreage basis. The trees under observation were planted during the spring of 1908, being set twenty-four feet apart by the square

system, which gives approximately seventy-five trees to the acre. Since planting, these trees have received good commercial culture. All figures given are based on the yields of almonds harvested.

A brief examination of the table shows that too much stress must not be laid on mere percentages, because during the 1916 season the normal set was much heavier than in 1917, but the crop of the latter year was by far the heavier. This is easily explained by the relatively heavier bloom during the spring of 1917. These figures also emphasize the importance of correct comparisons and show that the normal set must be carefully taken each year in order to secure a correct basis for the comparison of results obtained by artificial pollination.

TABLE II.—COMPARISON OF NORMAL SET WITH YIELD OF ALMONDS IN POUNDS (DRY WEIGHT) PER ACRE

Variety	1916		1917	
	Percentage set	Lbs. per acre	Percentage set	Lbs. per acre
California	14	869.4	7.3	865
Drake	15	1229.6	16.4	3800
Harriott	16	893.0	11.9	2240
I. X. L.	17	1059.4	16.5	1515
Jordan	13	817.0	3.6	455
King	29	660.4	25.7	1395
Languedoc	22	1763.4	16.5	745
Lewelling	37	1235.0	25.0	2035
Ne Plus Ultra	26	1714.6	20.4	3670
Nonpareil	24	869.4	28.2	2415
Peerless	20	888.4	7.0	895
Princess	17	935.0	17.7	1275
Reams	23	2044.4	14.0	2905
Texas	39	1657.6	21.7	1430
Average	22.3	1189.0	16.6	1885

NORMAL SET OF ALMOND VARIETIES

There is presented in table III a record of the normal set of various almond varieties under test at the University Farm. It will be noted that the normal set in the University orchards with open pollination ranged all the way from 3.6 per cent, in the case of the Jordan in 1917, to 39 per cent in the case of the Texas in 1916. Probably due to unfavorable weather conditions at the time of blossoming, the set during 1917, on the whole, was somewhat lower than that of the previous season, the average being 16.6 per cent as against 22.3 per cent for 1916. On account of the heavier bloom, however, the crop was

considerably heavier than during the preceding season. Attention is also called to the fact that in the orchard of Mr. G. W. Pierce (table VI) the set was considerably lower than at the University Farm. This is explained by the fact that in Mr. Pierce's orchard practically no insect pollen carriers were present. The orchard is properly inter-planted with pollenizing varieties.

TABLE III.—NORMAL SET OF FRUIT ON ALMOND VARIETIES, 1916–1917

University Farm, Davis, California

Variety	1916			1917		
	No. blossoms counted	No. fruits matured	Percentage matured	No. blossoms counted	No. fruits matured	Percentage matured
Big White Flat	.....	.....	....	1083	154	14.2
California	2402	326	14	2707	199	7.3
Drake	2141	336	15	2752	453	16.4
Golden State	.....	.....	....	1044	307	30.0
Harriott	1961	310	16	2301	274	11.9
I. X. L.	2131	363	17	2663	433	16.5
Jordan	1970	249	13	2593	94	3.6
King	1675	481	29	2512	647	25.7
Klondike	.....	.....	....	1069	329	30.4
Languedoc	2294	503	22	2488	419	16.5
Lewelling	2151	797	37	2653	664	25.0
Ne Plus Ultra	2071	531	26	1953	407	20.4
Nonpareil	1989	473	24	2647	748	28.2
Peerless	1975	396	20	1925	135	7.0
Princess	2085	356	17	2731	456	17.7
Silver Shell	.....	.....	....	742	136	17.7
Reams	1910	443	23	2001	280	14.0
Texas	2019	792	39	2568	654	21.7

SELF-STERILITY IN VARIOUS ALMOND VARIETIES, 1916–1917

Table IV gives the self-pollination records of the almond varieties tested for self-sterility during 1916 and 1917. From this table it will be noted that all of the seventeen varieties tested gave distinct evidence of self-sterility. The Harriott variety in 1916 proved self-fertile, but in 1917 was decidedly self-sterile. The probable explanation is that this is a variety which behaves like certain varieties of apples and pears which one season may be self-sterile, while another season they may be partly self-fertile. The results of these two seasons—1916 and 1917—and also for 1910 and 1911 are the same, viz., that for all practical purposes the cultivated almond is self-sterile and in all cases orchards must be inter-planted with pollenizing varieties if they are to prove commercially profitable.

TABLE IV.—SELF-POLLINATION OF ALMOND VARIETIES, 1916–1917
University Farm, Davis, California

Variety	1916			1917		
	No. blossoms self-pollinated	No. fruits matured	Percentage matured	No. blossoms self-pollinated	No. fruits matured	Percentage matured
Big White Flat	.....	....	.....	673	17	2.5
California	1586	2	.13	464	....	.....
Drake	996	1	.1	953	....	.....
Golden State	.....	....	.....	554	2	.4
Harriott	939	139	15.0	1189	1	.08
I. X. L.	740	4	.5	403	1	.25
Jordan	819	2	.2	597	....	.....
King	450	....	.....	900	....	.....
Klondike	.....	....	.....	404	2	.49
Languedoc	979	1	.1	625	....	.....
Lewelling	1031	10	.97	960	6	.63
Ne Plus Ultra	1005	6	.6	327	3	.9
Nonpareil	723	1	.14	446	1	.22
Peerless	976	....	.....	237	....	.....
Princess	822	....	.....	711	....	.....
Reams	1064	....	.....	1015	1	.09
Texas	1029	....	.....	994	2	.2

CROSSES BETWEEN CERTAIN ALMOND VARIETIES

Tables V and VI give the results of artificial cross-pollination during the years 1916, 1917 and 1918.

TABLE V.—CROSS-POLLINATION OF ALMOND VARIETIES, 1916–1917
University Farm, Davis, California

Variety	1916			1917		
	No. blossoms hand pollinated	No. fruits matured	Percentage matured	No. blossoms hand pollinated	No. fruits matured	Percentage matured
California						
× I. X. L.	.....	....	.....	211	7	3.3
× Jordan	.....	....	.....	258	15	5.8
× Ne Plus Ultra	.....	....	.....	257	10	3.9
× Nonpareil	.....	....	.....	250	32	12.8
× Peerless	.....	....	.....	208	17	8.2
Drake						
× California	.....	....	.....	505	124	24.6
× I. X. L.	.....	....	.....	514	78	15.1
× Jordan	.....	....	.....	274	65	24.6
× Languedoc	.....	....	.....	499	73	14.6
× Ne Plus Ultra	.....	....	.....	980	223	22.8
× Nonpareil	.....	....	.....	450	72	16.0
× Peerless	.....	....	.....	502	89	17.5
× Texas	.....	....	.....	511	101	20.0
Harriott						
× Ne Plus Ultra	.....	....	.....	568	83	14.6

TABLE V.—CROSS-POLLINATION OF ALMOND VARIETIES, 1916-1917 (*Continued*)

Variety	1916			1917		
	No. blossoms hand pollinated	No. fruits matured	Percentage matured	No. blossoms hand pollinated	No. fruits matured	Percentage matured
I. X. L.						
× Drake	.....	....	.....	145	2	1.4
× Jordan	.....	....	.....	264	7	2.7
× Lewelling	.....	....	.....	137	7	5.6
× Ne Plus Ultra	342	138	40	343	23	6.6
× Nonpareil	484	4	.8	412	....	....
× Peerless	.....	....	.....	404	12	3.0
Languedoc						
× California	.....	....	.....	502	65	12.9
× Drake	.....	....	.....	429	64	14.9
× I. X. L.	.....	....	.....	467	25	5.4
× Ne Plus Ultra	.....	....	.....	514	50	9.7
× Nonpareil	.....	....	.....	471	23	4.9
× Peerless	.....	....	.....	457	54	11.8
× Reams	.....	....	.....	475	36	7.6
× Texas	.....	....	.....	450	....	....
Lewelling						
× I. X. L.	.....	....	.....	424	28	6.6
× Ne Plus Ultra	.....	....	.....	373	24	6.4
× Nonpareil	.....	....	.....	244	18	7.5
Ne Plus Ultra						
× California (P)	.....	....	.....	308	24	7.8
× Drake	.....	....	.....	252	11	4.4
× Harriott	.....	....	.....	266	26	9.7
× I. X. L.	492	178	36	(P) 477	88	18.4
× Jordan (P)	.....	....	.....	160	20	12.5
× Lewelling	.....	....	.....	287	24	8.4
× Nonpareil	482	80	17	223	28	12.5
Nonpareil						
× I. X. L.	584	1	.17	283	1	.4
× Jordan	.....	....	.....	401	65	16.2
× Lewelling	.....	....	.....	258	57	22.1
× Ne Plus Ultra	402	140	26	.....	....	....
Reams						
× California	.....	....	.....	306	50	16.7
× I. X. L.	.....	....	.....	66	14	21.2
× Ne Plus Ultra	.....	....	.....	497	97	19.5
× Nonpareil	.....	....	.....	502	93	18.5
× Texas	.....	....	.....	509	131	26.7
Texas						
× California	.....	....	.....	528	47	8.9
× Drake	.....	....	.....	478	79	16.5
× I. X. L.	.....	....	.....	394	76	19.6
× Languedoc	.....	....	.....	499	....	....
× Nonpareil	.....	....	.....	557	97	17.8

NOTE.—(P) in above table indicates that crosses thus marked were performed in the Pierce orchards.

TABLE VI.—CROSSES ON THE NONPAREIL ALMOND, 1917–1918

Pierce Orchard, near Davis

Variety	1917			1918		
	No. blossoms pollinated	No. fruits matured	Percentage matured	No. blossoms pollinated	No. fruits matured	Percentage matured
Nonpareil						
Normal set	3346	94	2.8	2633	42	1.5
Self-pollinated	572	....	.....	356	....	....
× California	392	140	35.7	348	27	7.7
× Drake	366	47	12.7	370	82	22.0
× Eureka	.....	....	.....	259	23	8.8
× Golden State	.....	....	.....	292	59	20.2
× I. X. L.	237	....	.....	801	....	....
× Jordan	.....	....	.....	226	22	9.7
× Languedoc	.....	....	.....	477	114	23.9
× Ne Plus Ultra	406	51	12.5	320	78	24.3
× Peerless	396	63	15.8	322	53	15.9
× Texas	212	63	29.7	409	87	21.2

INTER-STERILITY BETWEEN ALMOND VARIETIES

In all the reciprocal crosses made, only the I. X. L. and Nonpareil and the Languedoc and Texas varieties seemed to give distinct evidence of inter-sterility. The case of inter-sterility between Languedoc and Texas has never before been recorded, so far as the writer knows. The inter-sterility between I. X. L. and Nonpareil has been experimentally proved in 1915, 1916, 1917 and 1918, and has also been experienced in practice by many growers.

The parentage of almond varieties at present grown in California is unknown and thus it is impossible to attempt an explanation of the inter-sterility of these varieties on the basis of relationships.

INFLUENCE OF POLLENIZERS ON CERTAIN ALMOND VARIETIES

During the season of 1916 reciprocal crosses were made only between the Nonpareil, I. X. L., and Ne Plus Ultra varieties and the results showed the first two to be not only self-sterile but also inter-sterile, i.e., unable to pollinate themselves or each other. The Ne Plus Ultra fertilized the other two and was in turn successfully fertilized by them.

More than 50,000 artificial cross-pollinations were made during each of the seasons of 1917 and 1918. The entire work of the latter season was lost by frost except the crosses on the Nonpareil. Likewise on account of unfavorable weather conditions rather negative

results were obtained with certain varieties during 1917 and consequently all discussion of these varieties is omitted. For the sake of brevity there has also been purposely left out of this publication much of the data collected, only sufficient being given to prove each point.

It is hoped that sufficient observations and experiments may be made during the next few seasons to enable the Division of Pomology to give exact information regarding the planting of orchards so as to insure the safe pollination of any variety of almond. The investigation of this problem has been confined neither to the varieties at present recommended for future planting nor to those now grown commercially in the state, a consideration of several kinds of minor importance having also been included. In making recommendations of varieties for interplanting, the writer has attempted to keep in mind the date of blooming, abundance of pollen and, to a limited extent, the productiveness and commercial value of the pollenizer.[6]

California.—The Nonpareil is a satisfactory pollenizer for the California. The results of the experiments with this variety have, up to the present, been somewhat negative.

Drake.—Eight varieties in all were used as pollenizers for the Drake, all of which gave satisfactory results. These varieties were the California, I. X. L., Jordan, Languedoc, Ne Plus Ultra, Nonpareil, Peerless and Texas. Preference should be given to the California, Languedoc, Nonpareil and Texas varieties.

Harriott.—The Ne Plus Ultra variety is a satisfactory pollenizer for the Harriott.

I. X. L.—Little weight should be attached to the results of the 1917 season's work with the I. X. L. variety on account of the difficulty experienced with weather conditions. A very low percentage of set was obtained with the pollen of all varieties used, but that of the Ne Plus Ultra proved the most satisfactory. Nonpareil pollen failed both seasons to set fruit on the I. X. L. The Ne Plus Ultra variety may be recommended for pollenizing the I. X. L.

Languedoc.—Of the eight kinds of pollen used to cross with the Languedoc, that of the California, Drake and Peerless varieties yielded the best results. Texas pollen set no fruit on the Languedoc. On account of its coincidence of bloom with the Languedoc variety the Drake should probably be recommended as a pollenizer.

Lewelling.—This variety was crossed with only three kinds of pollen—I. X. L., Ne Plus Ultra and Nonpareil, and none of these

[6] The reader will find a comprehensive discussion of the proper varieties for the commercial plantation in Taylor's "The Almond in California," Bull. No. 297, Calif. Expt. Sta.

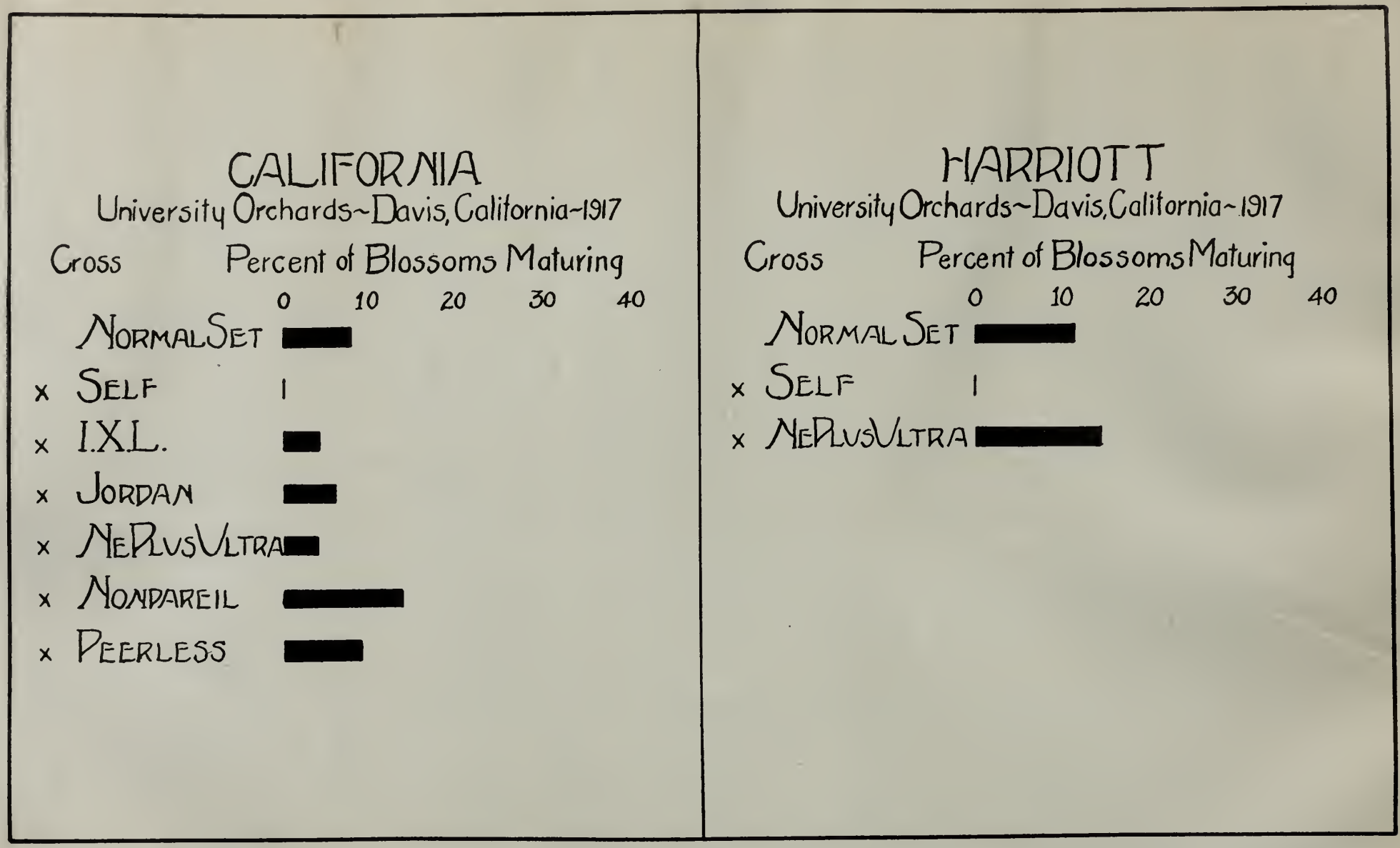


Fig. 3.—This chart shows the influence of the various kinds of pollen when applied to the flowers of the California and Harriott varieties. Note failure to set fruit when self-pollinated.

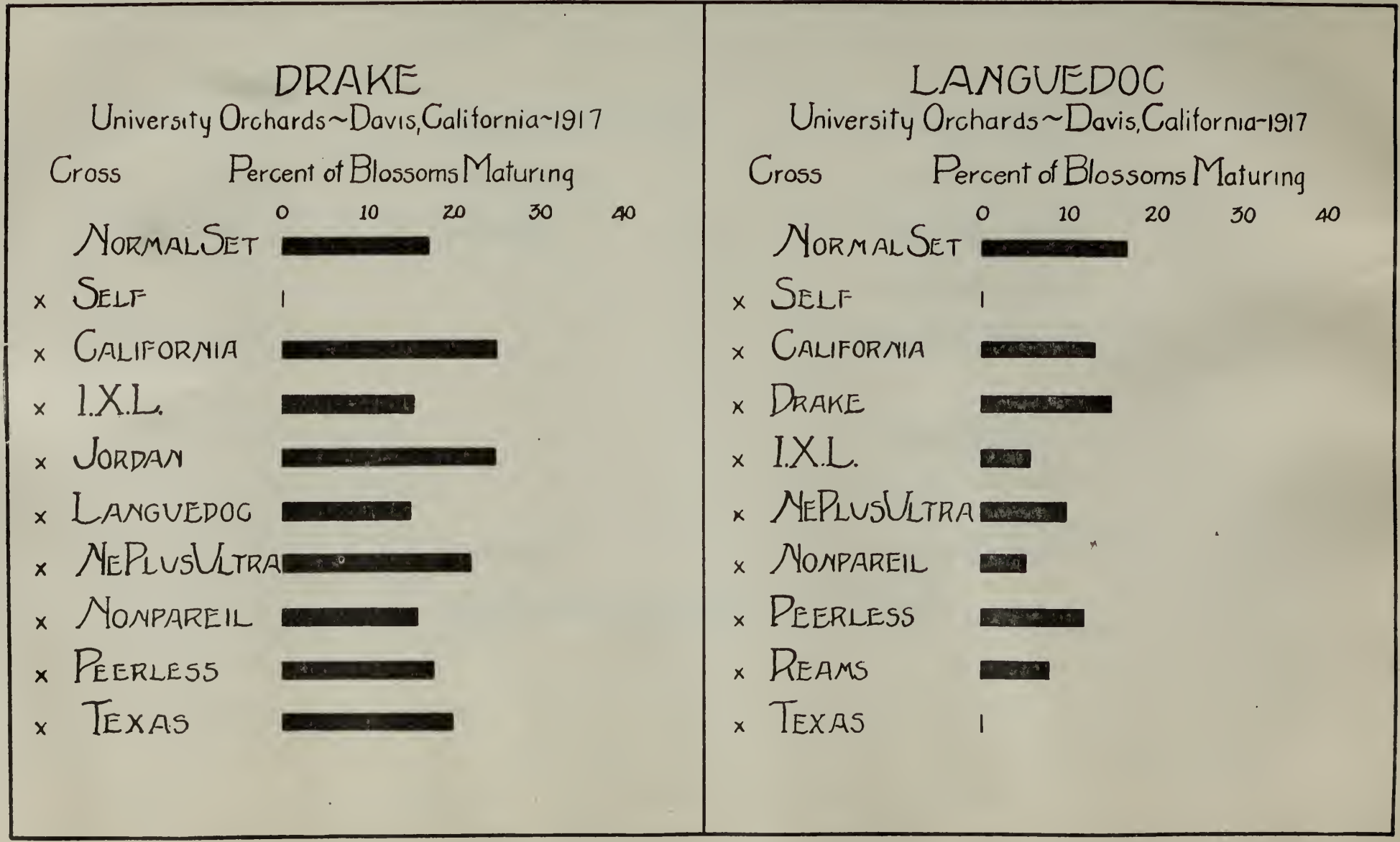


Fig. 4.—This chart shows the influence of the various kinds of pollen when applied to the flowers of the Drake and Languedoc varieties. Note failure to set fruit when self-pollinated; also failure of Texas pollen to set fruit on the Languedoc.

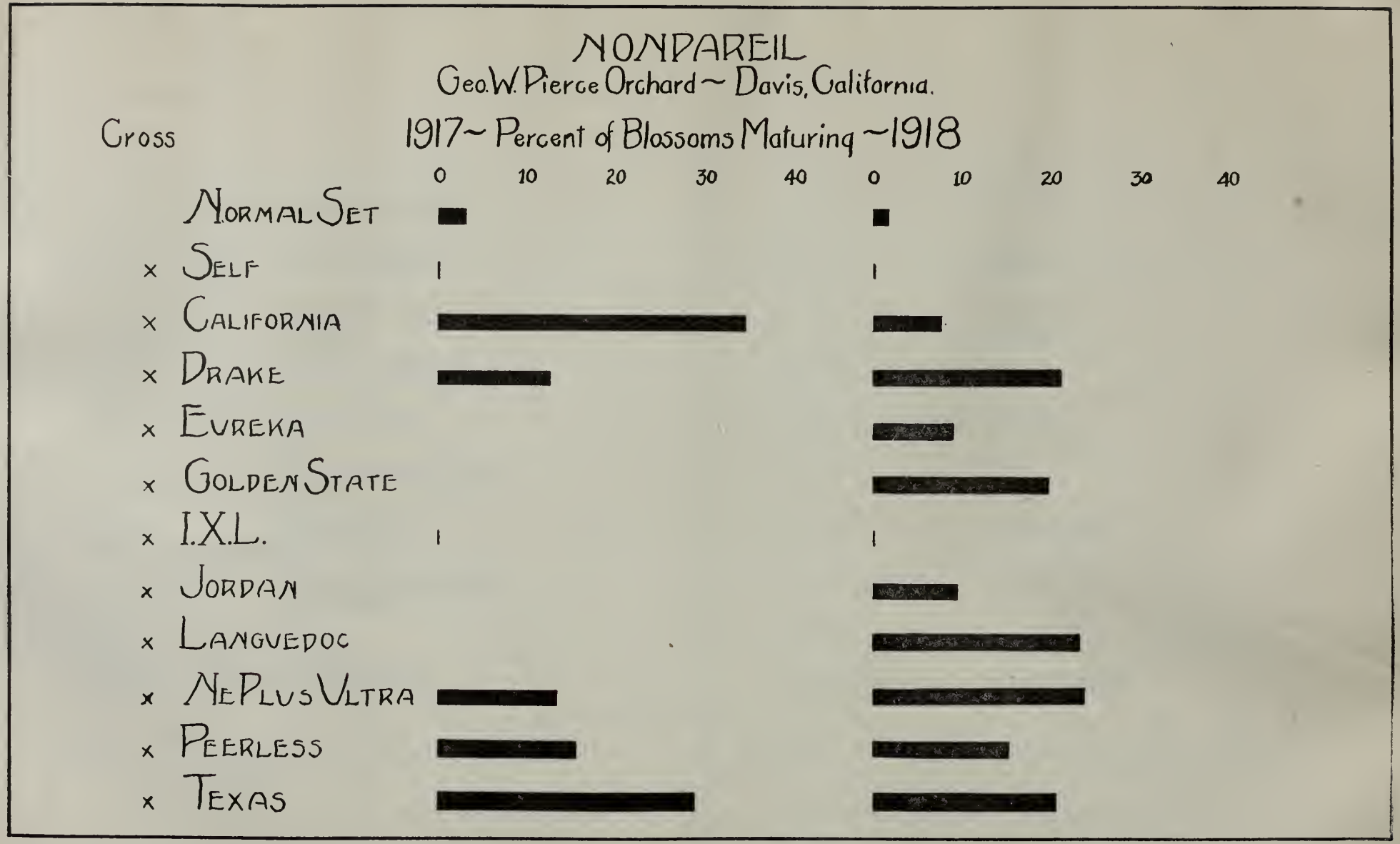


Fig. 5.—This chart shows the influence of various kinds of pollen when applied to the flowers of the Nonpareil variety. Note failure to set fruit when self-pollinated. Also the inability of I. X. L. pollen to set fruit on the Nonpareil.

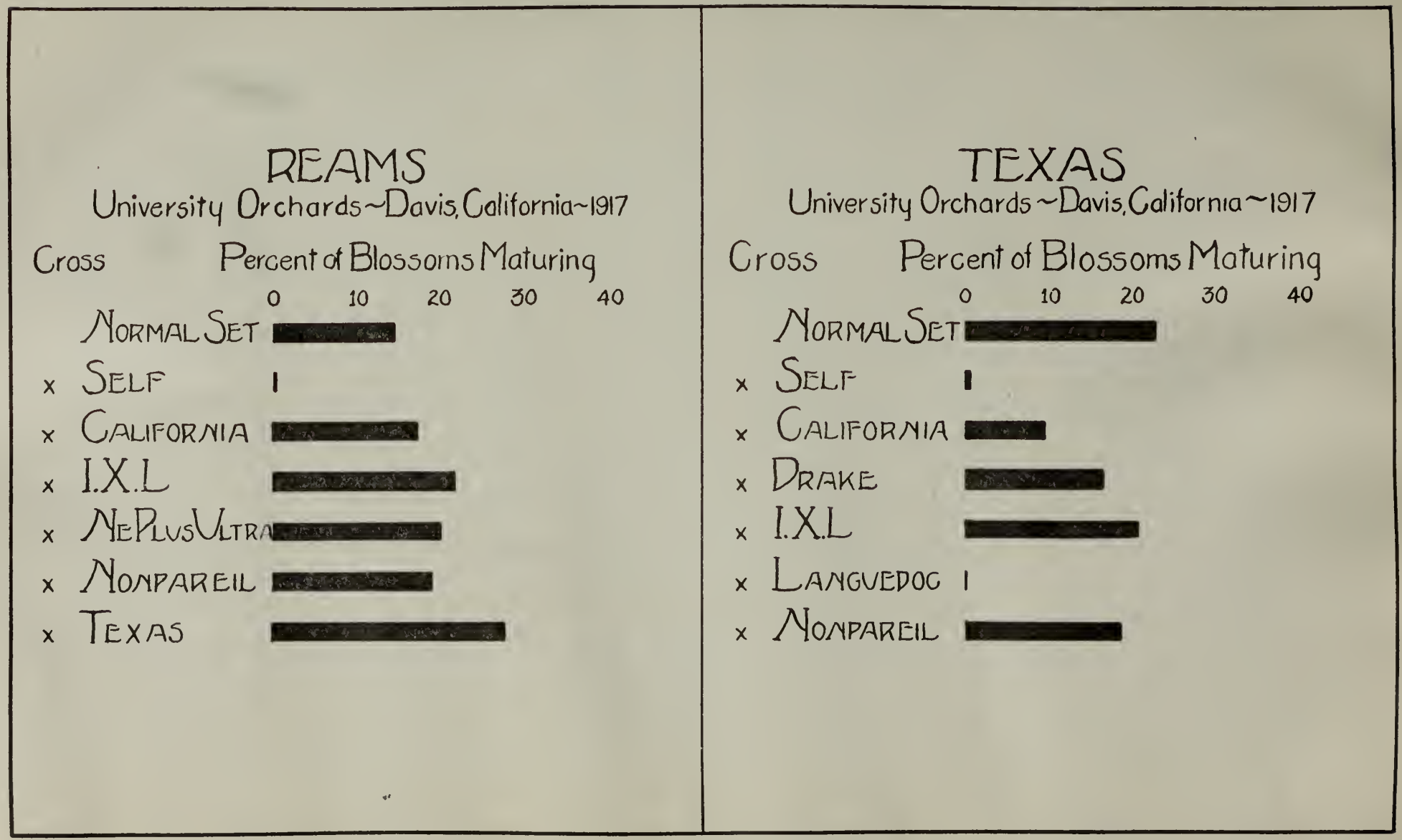


Fig. 6.—This chart shows the influence of the various kinds of pollen when applied to the flowers of the Reams and Texas varieties. Note failure to set fruit when self-pollinated. Also the inability of Languedoc pollen to set fruit on the Texas.

yielded even one-third as high a set as the insect-pollinated flowers. (The bees had easy access to many other varieties in addition to the three mentioned.)

Ne Plus Ultra.—Pollen from eight varieties was used in the crossing experiments with Ne Plus Ultra. California, I. X. L. and Jordan gave every promise of being exceedingly good pollenizers for the Ne Plus Ultra. The final percentages shown in the table should not have too much weight due to the fact that many of the fruits set did not come to maturity on account of mechanical injury, loss in cultivation, etc. The Nonpareil is also a satisfactory pollenizer for the Ne Plus Ultra variety.

Nonpareil.—Of the eleven varieties tested as pollenizers for the Nonpareil only the I. X. L. failed to set a crop. During 1917 the California was preëminently the best. During the 1918 season the Drake, Ne Plus Ultra, Texas and Languedoc set very satisfactory crops on the Nonpareil. Preference should be given the California, Drake, Ne Plus Ultra and Texas varieties.

Reams.—The Drake, I. X. L., Ne Plus Ultra, Nonpareil and Texas varieties gave entirely satisfactory results as pollenizers for the Reams. Preference should be given the Texas.

Texas.—The Drake, I. X. L. and Nonpareil varieties gave fair results as pollenizers for the Texas, although the percentage set in each case was not quite equal to the normal set. Pollen of the Languedoc variety set no fruit on the Texas.

POLLENIZING AGENCIES

After having planted inter-fertile varieties the orchardist should, by all means, provide an agency for the transfer of the pollen from the trees of one variety to those of another. The common honey bee is by far the best carrier of pollen and it will pay the grower to keep bees although he may not care to go into the honey business. Bees, however, are a very profitable side line for the orchardist, especially if alfalfa fields are available to work on after the blooming season of fruit has passed. About one hive of bees to an acre of bearing orchard should be provided. Preferably the hives should be scattered as widely as possible throughout the orchard during the blooming season. Experiment and experience have shown that little reliance can be placed on the efficacy of wind and insects, other than the honey bee, in effecting the transfer of pollen from tree to tree, or, in fact, from flower to flower.

Eliminating from consideration all conditions which may influence the fruitfulness of an orchard except those occurring at blooming time, it may be said that the set is largely influenced by weather conditions at time of blooming. Cold weather, aside from killing the blossoms or lowering the vitality of the pollen, often prevents bees from working. The same would be true if cloudy, wet and windy weather prevail. For their best work bees demand clear, warm and quiet days and since the weather at the time almonds bloom is often quite unsettled, it is readily seen that the blooming period of the various pollenizing varieties should overlap perhaps a week in order that there may be one or two days at least when the weather will be favorable for insect pollination.

As a case in point mention may be made of the 1917 blooming season of almonds. Many almond growers had, during this season, a light crop—not due to lack of proper varieties, nor to freezing cold, but due to the existence of such weather conditions throughout the blooming period that the bees were prevented from working. This point further illustrates the great necessity of having in the orchard a large number of these "helpers."

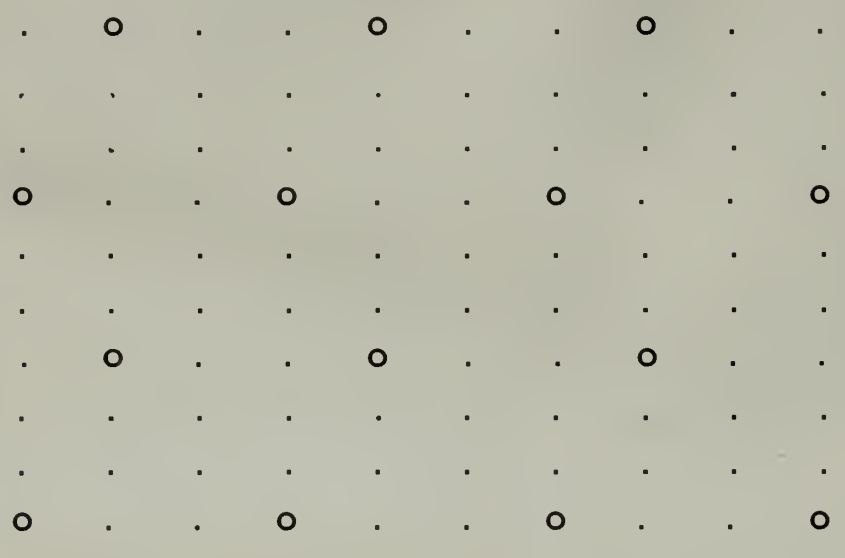
ARRANGEMENT OF THE ORCHARD FROM A POLLINATION STANDPOINT

In planting an orchard it is desirable to have at least every sixth and preferably every fourth row of a pollenizing variety. For convenience in harvesting, it is best to plant two rows of one kind, then two rows of the pollenizing variety, and so on; or, if it is desired to have more of one variety than another, four rows of the favorite variety and then two rows of the pollenizer, and repeat. For various reasons, it is often desirable to reduce the number of pollenizing trees to the minimum. Under these circumstances, one tree in twenty-five is perhaps sufficient, although at least one tree in eight is strongly recommended. It is seldom wise to graft over a part of a tree to the pollenizing variety as this tends towards confusion and expense in harvesting.

In planting one tree of the pollenizer to seven or eight of the main variety, the pollenizer should be placed as every third tree in every third row in such a way that the spaces in the pollination rows are broken as shown on the following page, the o in each case representing a pollenizer tree.

If by chance a self-sterile variety has been planted in a solid block, the necessary pollinator may be introduced by grafting. Some relief may be obtained during the years while waiting for the trees grafted

over to pollenizing varieties, to come into bearing, by cutting off large limbs of pollenizing varieties, placing the cut ends in buckets of water and distributing the same throughout the orchard during the blooming period. Such limbs will live for several days and continue to bloom, forming pollen for the bees to transfer to the self-sterile variety.



SUMMARY OF ALMOND POLLINATION

1. Satisfactory artificial germination of almond pollen was secured in a 12 per cent cane sugar solution.

2. Inclement weather conditions undoubtedly injured the viability of the almond pollen produced during the blooming seasons of 1917 and 1918.

3. There is considerable variation in the amount of pollen produced by the various almond varieties.

4. Almond varieties may be roughly divided into two classes: early bloomers and late bloomers, when the length of their effective full bloom is considered.

5. The first blossoms produced by certain almond varieties each season may yield a smaller amount of pollen and pollen which is inferior in viability to that produced by flowers on the same tree maturing several days or a week later.

6. Pollenizing agencies, such as the honey bee, are necessary to the set of a good crop of fruit.

7. The Harriott variety, which during the season of 1916 proved able to set fruit with its own pollen, the following season proved self-sterile.

8. All almond varieties thus far tested have proved self-sterile, at least in certain years. All of the seventeen varieties tested during

the season of 1917 proved self-sterile. This list includes the Big White Flat, California, Drake, Golden State, Harriott, I. X. L., Jordan, King, Klondike, Languedoc, Lewelling, Ne Plus Ultra, Nonpareil, Peerless, Princess, Reams, Texas and a hardshell seedling.

9. Certain almond varieties are inter-sterile.

10. The I. X. L. and Nonpareil varieties proved practically inter-sterile during the two seasons' work.

11. The Languedoc and Texas are inter-sterile, as shown by the results of 1917.

12. The California at present seems to be the one best pollenizer for all varieties thus far tested, which have a coincident period of bloom.

13. The *California* may be pollinated by the Nonpariel and Peerless.

The *Drake* may be pollinated by the California, Languedoc, Nonpareil and Texas; however, the Languedoc is a poor pollen producer.

The *Harriott* may be pollinated by the Ne Plus Ultra.

The *I. X. L.* may be pollinated by the Ne Plus Ultra.

The *Languedoc* may be pollinated by the Drake.

The *Ne Plus Ultra* may be pollinated by the California, I. X. L., Jordan and Nonpareil.

The *Nonpareil* may be pollinated by the California, Drake, Jordan, Ne Plus Ultra, Peerless, and Texas.

The *Reams* may be pollinated by the Texas.

The *Texas* may be pollinated by the Drake and Nonpareil.

14. One colony of honey bees should be provided for each acre of orchard.

15. Care should be taken in the arrangement of varieties in the orchard to facilitate cross-pollination and convenience in harvesting.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation of the assistance he has received from students and colleagues. Messrs. M. B. Weidenthal and Henry Schlapp, senior students in the University of California, performed certain phases of the work as thesis problems, and without their help it would have been impossible to have made so many pollinations. Messrs. M. N. Wood, G. L. Philp, and Miss R. M. Amesbury, members of the Division of Pomology, also rendered invaluable assistance in the field and laboratory. Dr. W. L. Howard, also of this Division, has given great service in suggestions and criticisms. Mr. Geo. W. Pierce kindly allowed the use of his orchard for certain experiments which could not be carried out in the University orchards.

Fig. 7.—Only two fruits from 349 blossoms left open to natural conditions (normal set). Only that portion of the branch bearing fruit is shown in the photograph. A typical example of the normal set in the Pierce orchard, 1918.

Fig. 8.—No fruit set on branch of Nonpareil which was pollinated with its own pollen. Twenty-eight blossoms set no fruit. A typical cluster of Nonpareil when self-pollinated. Pierce orchard, 1918.

Fig. 9.—Six Nonpareil fruits set from fifteen blossoms pollinated with California pollen. A typical cluster resulting from crossing Nonpareil with California. Pierce orchard, 1918.

Fig. 10.—Twelve Nonpareil fruits set from thirty-one blossoms pollinated with Golden State pollen. A typical cluster resulting from crossing Nonpareil with Golden State. Pierce orchard, 1918.

Fig. 11.—No fruits set on branch of Nonpareil which was pollinated with I. X. L. pollen. Fifteen blossoms set no fruit. A typical cluster resulting from crossing Nonpareil with I. X. L. Pierce orchard, 1918.

Fig. 12.—Fifteen Nonpareil fruits set from twenty-eight blossoms pollinated with Languedoc pollen. A typical cluster resulting from crossing Nonpareil with Languedoc. Pierce orchard, 1918.

Fig. 13.—Fourteen Nonpareil fruits set from twenty-nine blossoms pollinated with Ne Plus Ultra pollen. A typical cluster resulting from crossing Nonpareil with Ne Plus Ultra. Pierce orchard, 1918.

Fig. 14.—Nine Nonpareil fruits set from twenty blossoms pollinated with Peerless pollen. A typical cluster resulting from crossing Nonpareil with Peerless. Pierce orchard, 1918.

Fig. 15.—Twelve Nonpareil fruits set from twenty-nine blossoms pollinated with Texas pollen. A typical cluster resulting from crossing Nonpareil with Texas. Pierce orchard, 1918.